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FLAME BARRIER CUSHIONING FOAMS AND UPHOLSTERY LAYER CONSTRUCTION INCORPORATING SUCH FOAMS

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FLAME BARRIER CUSHIONING FOAMS AND UPHOLSTERY LAYER CONSTRUCTION INCORPORATING SUCH FOAMS

This invention relates to flexible polyurethane foams forming at least a portion of an upholstery layer in a bedding or a furniture construction, wherein said foams have a lower density and a desired indentation force deflection, and form a flame barrier to shield more combustible materials in the bedding or furniture construction from ignition by flame.

BACKGROUND OF THE INVENTION

Polyurethane foams with varying density and hardness may be formed. Hardness is typically measured as IFD ("indentation force deflection") or CFD ("compression force deflection"). Specifically, IFD_{25} is the force required to compress the foam to 25% of its original thickness or height. Tensile strength, tear strength, compression set, air permeability, fatigue resistance, support factor, and cell size distribution may also be varied, as can many other foam properties. Specific foam characteristics depend upon the selection of the starting materials, the foaming process and conditions, and sometimes on the subsequent processing.

Cellular polyurethane structures typically are prepared by generating a gas during polymerization of a liquid reaction mixture comprised of a polyester or polyether polyol, an isocyanate, a surfactant, catalyst and one or more blowing agents. The gas causes foaming of the reaction mixture to form the cellular structure. The surfactant stabilizes the structure.

Untreated cellular polyurethane structures tend to have relatively high flammability, and open flame ignition continues to be a concern where polyurethane foams are incorporated into bedding and furniture. Many mattresses and upholstered furniture articles must meet stringent flammability standards, such as the California Technical Bulletin 603 developed by the California Bureau of Home Furnishings for mattresses. Under the California TB603 standard, a mattress must not reach a heat release rate in excess of 200 kW in the first one-half hour after

ignition using a specified energy source. The mattress also cannot exceed a total heat release of 10 MJ in the first ten minutes. Experimentally, it has been found that extremely flame resistant materials should be incorporated into the outer layers of the mattress construction in order to satisfy the California TB603 standard.

Some polyurethane foams are made more resistant to flame ignition by incorporating flame retardants in situ into the foam-forming composition. Often, when flame retardants are incorporated in situ, particulate matter is incorporated into the foam structure. Foams formed with flame retardants in situ tend to have less desirable cushioning properties than foams without such additives. It is also more difficult to load large amounts of flame retardant into foams in situ to further increase flame retardance, and larger flame retardant loadings further detract from foam cushioning properties.

Higher levels of flame retardance can be achieved by impregnating a polyurethane foam with a coating that incorporates one or more flame retardants. Unfortunately, however, binder-coated foams typically also have higher compression resistance (hardness), and do not provide the same cushioning support that is achieved with untreated foams. Thus, in situ flame retardant foam cushions have been preferred, notwithstanding the fact that higher flammability retardance is still desired.

Mattress constructions and furniture upholstery constructions have obtained higher flame resistance by incorporating a fabric or a fiber flame barrier between the upholstery fabric and the cushioning materials (fiber fill or foam) and support structure (springs or foam cushions) within the constructions. The treated fabric or fiber flame barrier provides the needed flame retardance, but has little or no cushioning effect. Hence, either the comfort of the construction is reduced or additional foam or other cushioning material is incorporated into the construction in conjunction with the fabric or fiber flame barrier to restore the original cushioning of the construction. Better cushioning or lower cost mattress or furniture constructions would be produced if such a fabric

or fiber flame barrier could be eliminated.

SUMMARY OF THE INVENTION

According to a first aspect of the invention, an upholstery construction for a mattress or an article of furniture includes a fabric layer having a front surface and a back surface and a flame barrier foam sheet proximate to the back surface of the fabric layer. The flame barrier foam sheet comprises a polyurethane foam sheet that is coated or impregnated with a coating of one or more binders and one or more flame retardants, and dried. After it has been coated or impregnated and dried, the flame barrier foam sheet has a density of in the range of about 1.0 to 6.0 pcf and an compression force deflection (CFD_{25}) of in the range of about 0.1 to 0.4 psi.

Preferably, the flame barrier foam sheet is adjacent to the back surface of the fabric layer. Most preferably, when incorporated into a mattress, the upholstery construction is quilted such as by stitching together the flame barrier foam sheet and fabric layer in combination with one or more other layers. The one or more other layers may include a second foam sheet and a nonwoven backing sheet. If included, the second foam sheet preferably is installed adjacent to the flame barrier foam sheet, such as between the flame barrier foam sheet and the backing sheet.

The coating preferably is a liquid or an aqueous solution that includes a liquid binder in combination with one or more fire retardants, which may be solid or liquid or a combination thereof. Preferably, the binder in the coating has a glass transition temperature (Tg) of less than about 10°C, most preferably less than about 0°C. The binder in the coating may be selected from materials generally characterized as latexes, such as those based on natural rubber, polyvinyl chloride, ethylene vinyl chloride copolymer, vinyl acetate, vinylidene chloride copolymer and vinyl acetate copolymer chemistry. Other binders may also be used, such as those based on acrylonitrile, epoxy, polychloroprene and polyurethane. Any mixture of the identified binders may also be used. Most preferably, the binder in the coating has a chlorine content of at least

about 20% on a dry weight basis.

The solid flame retardant in the coating preferably is selected from the group consisting of: melamine, a melamine derivative, aluminum trihydrate, polyvinyl chloride, antimony oxide, expandable graphite, magnesium hydroxide, urea, an amino phosphorous compound such as ammonium polyphosphate, and mixtures thereof. A liquid flame retardant may also be included in the coating.

Preferably, the flame barrier foam sheet prior to being coated or impregnated has a density of less than about 1.5 pcf and an indentation force deflection (IFD_{25}) of about 15 lb-force or less. After coating, the coated or impregnated flame barrier foam sheet preferably has a density of from about 2.0 to about 4.5 pcf.

According to a second aspect of the invention, a mattress or an article of upholstered furniture incorporates the upholstery construction. The upholstery construction preferably is quilted when incorporated into a mattress. The flame barrier foam may be first wrapped over a cushion and then installed proximate to the fabric layer when incorporated into an article of furniture.

DESCRIPTION OF THE FIGURES

The invention will be more fully understood by referring to the detailed specification and claims taken in connection with the following drawings. For the purpose of illustrating the invention, certain embodiments are shown in the drawings. It is understood, however, that this invention is not limited to the precise arrangements shown.

FIG. 1 is a schematic drawing of an apparatus to coat or impregnate a foam sheet with an aqueous solution containing one or more flame retardant compounds carried by a binder;

FIG. 2 is schematic cross-sectional view in side elevation of an upholstery construction for a mattress or an article of furniture according to the invention;

FIG. 3 is a schematic cross-sectional view in end elevation of a mattress incorporating the upholstery construction of FIG. 2; and

FIG. 4 is a schematic side elevational view of a test configuration for testing the flame retardancy of a flame barrier according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIG. 1, an impregnation method is shown. A polyurethane foam sheet **10** is provided. Preferably, the polyurethane foam sheet **10** has a thickness in the range of 0.25 to 0.5 inches. Other cushioning foams besides polyurethane foam, and other foam thicknesses, may be used.

To achieve the desired cushioning properties in the flame barrier foam sheet of the final upholstery construction, the polyurethane foam forming the foam sheet **10** preferably has a density of less than about 1.5 pounds per cubic foot (pcf), and an IFD_{25} of about 15 or less, more preferably about 12 or less. Of course, if different cushioning properties are desired, foam sheets with different IFD_{25} values outside these preferred values may be used.

IFD or "indentation force deflection" is determined in accord with a procedure similar to ASTM D 3574. In this case, for IFD_{25} a foam sample is compressed by 25% of its original height and the force after one minute is reported. Foam samples should be cut to a size 15" x 15" x 4" prior to testing.

Referring again to FIG. 1, the polyurethane foam sheet **10** is passed over a roller **12** and into a dip pan **14** that contains a coating liquid **16**. The foam sheet **10** picks up a quantity of the coating **16** and is then passed between a set of nip rollers **18**. The amount of impregnation or coating pick up can be adjusted by varying the gap between the nip rollers **18** and/or adjusting their speed of rotation. A portion of the coating liquid **16** is squeezed out of the foam sheet **10** by the nipping action of the nip rollers **18** and returns to the dip pan **14**. From the nip rollers **18**

the impregnated foam sheet **10** is passed through one or a series of drying ovens **20**. The drying oven **20** may be a radiant heating oven, a convective heating oven or a series of conductive heating elements, or it may be any combination thereof. The coating is dried or cured in the drying oven **20** before the impregnated foam sheet that may form a flame barrier foam sheet **24** is wound over a take up roller **22**.

The coating liquid **16** may include an aqueous or solvent based binder selected from the group generally characterized as latexes, such as those based on acrylic, natural rubber, polyvinyl chloride, ethylene vinyl chloride copolymers, vinyl acetate, vinylidene chloride copolymers, and vinyl acetate ethylene copolymers. Other binders suitable for use with polyurethane foam may also be used, such as those based on acrylonitrile, epoxy, polychloroprene and polyurethane. A combination of one or more such binders may be included in the coating liquid. Preferably, the binder forming the coating liquid has a glass transition temperature (Tg) of less than 10°C, most preferably, less than 0°C. Preferably, the binder has a chlorine content of at least about 20% on a dry weight basis.

The binder may be filled with one or more liquid or solid flame retardant materials to form the coating liquid. Preferably, the solid flame retardants are selected from the group consisting of polyvinyl chloride, melamine, melamine derivatives, aluminum trihydrate, antimony oxide, expandable graphite, magnesium hydroxide, urea, or an amino phosphorous compound, such as ammonium polyphosphate. Preferably, the liquid flame retardants are selected from the group consisting of brominated and chlorinated organic compounds, such as commercially available tetrabromobenzoate esters or chlorinated diphosphate esters. When incorporated, the liquid fire retardant level typically is expected to be less than 25% of the solid fire retardant level.

The solids level for the impregnating or coating formulations that remain on the polyurethane foam sheet to form the flame barrier foam sheet may be set forth as the percentage

of the coating that remains with the foam after drying or curing. The solids level represents the percentage of the formulation that is not volatile or aqueous. The solids level may be adjusted, for example, to change the viscosity of the coating liquid or to minimize the amount of drying time required. This solids level adjustment is typically achieved by adjusting the amount of water added to the coating formulation. Although the invention is not limited to this range, a typical solids level for the coating or impregnating formulations is between 40 and 60%.

The binder load factor may be set forth as the ratio of total dry weight of the coating/impregnation material to the total dry weight of the binder. The binder load factor affects the adhesion of the coating to the polyurethane foam sheet. Although the invention is not limited to this range, a typical load factor for the coating or impregnating formulations is in the range of 3 to 12.

Referring next to FIG. 2, an upholstery construction **26** is formed by layering the elements that form the construction. The embodiment shown in FIG. 2 is a quilted upholstery construction **26** suitable for a mattress. A similar upholstery construction (although usually not quilted) may be used in an article of upholstered furniture. A fabric layer **28** forms the outer covering of the mattress. One exemplary fabric layer **28** for a mattress is a knit or woven stretch fabric comprising a blend of cotton and polyester, such as 75% cotton and 25% polyester.

The flame barrier foam sheet **24** is positioned adjacent to the fabric layer **28.** Next, a second foam layer **29** is positioned adjacent to the flame barrier foam sheet **24**. Finally a nonwoven backing **30** is positioned adjacent to the second foam layer **29**. The upholstery construction **26** is shown with both a flame barrier foam sheet **24** and a second foam layer **29**; however, it is also possible to form the construction without such second foam layer **29**. The layers forming the bedding upholstery construction **26** preferably are joined together, such as by sewing.

In a furniture upholstery construction, the flame barrier foam sheet **24** would wrap a

cushion core, and the flame barrier foam sheet and cushion core would be encased in the upholstery fabric layer **28**. A second foam sheet **29** and a nonwoven backing **30** would not normally be used. The upholstery fabric would be sewn together to enclose the flame barrier foam sheet and cushion core to form an upholstered furniture cushion.

Referring next to FIG. 3, a mattress **34** is formed with the upholstery construction **26** of FIG. 2. Sections of the upholstery construction **26** form the outer top and bottom surfaces of the mattress **34.** In addition, a flame barrier foam sheet **24** in combination with an outer fabric **28** and a nonwoven backing **30** form the outer side surfaces of the mattress **34**. The innerspring unit **36** or other support structure is thus encased within the flame barrier foam sheets forming the upholstery construction **26** at the top and bottom, and the flame barrier foam sheet(s) along the sides of the mattress. The flame barrier foam sheets thus shield the support structure of the mattress from ignition sources that could cause the support structure to ignite. In the Examples set out below, the mattress support structure is a slab of polyurethane cushioning foam. Other support structures, such as encased innersprings, or innersprings in combination with cushioning foams or other cushioning materials may be formed.

The flame barrier foam sheet according to the invention resists yellowing from exposure to UV light or NOx gases. As compared to equivalent foam compositions that were not coated or impregnated with flame retardant filled binder, at least a fifty percent (50%) reduction in yellowing as measured on the Delta b scale was measured for samples that were exposed to 8 ppm NO_2 gas, and also measured for samples exposed to accelerated ultraviolet light in a QUV weathering unit. This is an advantage particularly for flame barrier foam sheets used in upholstery constructions for mattresses and furniture where the flame barrier foam sheet is placed directly in contact with the surface fabric. Color fastness of the flame barrier foam sheet will avoid or minimize changes in the color(s) of the surface fabric visible to consumers.

The invention is further illustrated, but not limited by, the following examples.

EXAMPLES

Table 1 below sets out the composition of three exemplary coating liquids that were used. Unless otherwise indicated, amounts are reported as wet parts per hundred based on the weight of the liquid.

Table 1

	Coating 1	Coating 2	Coating 3
Water	40.102	37.216	39.919
AF-4500	--	17.927	--
TR 520	9.705	--	--
RHOPLEX FR-1	--	--	12.007
Aluminum trihydrate	46.117	44.734	47.994
AB100	3.008	--	--
Antimony oxide	1.016	--	--
Kelzan	0.053	0.019	0.012
BYK-020	--	0.109	0.067
Target total solids	54.9%	53.8%	54.0%
Binder Load Factor	11.3	6.0	9.0

The Binder Load Factor is the ratio of total dry weight of the coating to the total dry weight of the binder (e.g., TR 520 for Coating 1, AF-4500 for Coating 2, and FR-1 for Coating 3). The target total solids level is the percentage of the formulation that is not volatile or aqueous, and thus the percentage of the coating or impregnation material that remains with the foam after drying or curing.

AF-4500 is an ethylene vinyl chloride binder supplied by Air Products and Chemicals Corp. TR 520 is an acrylic latex binder supplied by Rohm and Haas Co. RHOPLEX FR-1 is a

polyvinylidene chloride copolymer binder supplied by Rohm and Haas Co.

Aluminum trihydrate was a commercial grade. AB100 is a chlorinated phosphate ester liquid flame retardant supplied by Albemarle Corp.

Antimony oxide is a fire retardant synergist supplied by Great Lakes Chemical Co.

BYK-020 is an anti-foaming agent supplied by BYK-Cheme.

Kelzan is a rheology modifier supplied by CP Kelco US, Inc.

Coatings 1, 2 and 3 were impregnated onto sheets of polyurethane foam using an impregnation process substantially as set forth and describe above. In each case, the starting foam sheet had a thickness of from 3/8 to 1/2 inch, a density of 1.1 pcf and an IFD_{25} of about 9.0 lb-force.

Table 2 below sets out the thickness, density and compression force deflection values for the coated foam samples produced using the coating compositions of Coatings 1, 2 and 3. The exemplary flame barrier foams were denominated A to F for ease of reference. For comparison, Table 2 further sets out the thickness, density and compression force deflection values for commercially available flame barrier foams of Foamex International Inc. and Chestnut Ridge Foam Inc.

25% CFD was measured using the procedure set forth in ASTM D 3574. 25% CFD or CFD_{25} or "compression force deflection" is a measure of the load-bearing properties of the foam and is calculated by dividing the force required to depress a circular platen into a 2" x 2" foam sample to deflect the foam to 25% of its original foam height by the cross-sectional area of the sample. Thus, the units for CFD are pounds per square inch or "psi".

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Table 2

Example	Coating	Density (pcf)	CFD_{25} (psi)	Thickness (in)
A	2	2.0	0.22	0.36
B	2	3.3	0.24	0.35
C	1	3.9	0.26	0.36
D	3	4.6	0.26	0.29
E	3	3.9	0.25	0.31
F	3	3.4	0.22	0.28
SAFLITE	--	9.8	1.95	0.37
SAFGUARD	--	7.2	0.83	0.38
FIRESEAL	--	5.7	0.59	0.30

FIRESEAL is coated flame retardant polyurethane foam supplied by Foamex International Inc. SAFLITE and SAFGUARD are other coated flame retardant foams supplied by Chestnut Ridge Foam Inc. These coated foams are typically used to build mattresses for the healthcare, correctional and university dormitory markets.

The commercially available foams FIRESEAL, SAFLITE and SAFGUARD have higher densities and higher CFD_{25} than the flame barrier foam sheets incorporated into the upholstery constructions of the invention. Thus, the flame barrier sheets impregnated or coated with binder add less weight and provide greater cushioning support to a mattress construction.

Certain of the flame barrier foam sheets of the examples set out in Table 2 were then used to form upholstery constructions. The upholstery or quilting constructions included a top layer of stretch bedding fabric (75% cotton and 25% polyester), a next layer of the flame barrier foam sheet, a next layer of 1.0 inch thick polyurethane cushioning foam that had a density of about 0.7

pcf and an IFD25 of about 7 lb-force, and finally a nonwoven backing layer. Simulated bedding mattresses were then constructed using the upholstery constructions in order to evaluate the comfort and cushioning characteristics as compared with other flame barrier materials. The quilting constructions were placed on the top of a supportive foam base. The supportive foam base was a polyurethane foam slab cut to 8 inches thick. The supportive foam base had a density of 2.0 pcf and an IFD_{25} of 51 lb-force.

These mattresses were compared for comfort with mattresses formed with the same polyurethane foam slab, stretch bedding fabric, cushioning polyurethane foam and nonwoven backing in combination with competitive flame barrier fabrics instead of the coated or impregnated polyurethane foam flame barrier sheet as used in Examples A and C. The three flame barrier fabrics tested were Chiquola S2574 and TexTech 8163B and 8204B. All of these flame barrier fabrics are marketed as suitable for use in mattresses, and are indicated as having ability to pass the California TB603 flammability test, as described above.

The upholstery or quilt constructions including the flame barrier foam sheets of Examples A and C, and the quilt constructions including S2574, 8163B and 8204B were placed over the supporting foam base. A190 lb. adult reclined on the quilt construction and foam base as part of a pressure map test using an FSA unit purchased from Vista Medical. Five pressure measurements were taken for each sample, and these measurements were then averaged. Each test yielded an average pressure over the surface area in contact with the quilt construction. The results are reported in Table 3 below.

Table 3

	Example A	Example C	S2574	8163B	8204B
Av. Pressure (mmHg)	14.9	14.2	16.9	15.4	15.6

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Lower average pressures indicate greater comfort. Thus, Example C had the lowest average pressure.

A full mattress prototype was built using the quilted upholstery construction of Example C. The mattress had a quilt construction with a cover fabric (of 75% cotton and 25% polyester), the flame barrier of Example C, a one-inch thick sheet of QUILTFLEX polyurethane foam (supplied by Foamex International Inc.), and a nonwoven backing. The QUILTFLEX foam had a density of about 0.7 pcf and an IFD_{25} of about 7 lb-force. The side border panels also used the cover fabric, flame barrier and nonwoven backing, but eliminated the sheet of QUILTFLEX foam.

The mattress so made was sent to the California Bureau of Home Furnishings for testing under the TB603 flammability standard. The mattress passed the flammability standard test as set forth below, and was reported to have been more than 95% recovered.

	Results	Requirement
Max. rate of heat release (kW)	15	Less than 200 kW in 30 min.
Total heat release at end of test (MJ)	3	Less than 10 in first ten min.
Max. ceiling temperature (°F)	185	
Total smoke release at end of test (m^3)	16	
Total test duration (min:sec)	10:01	30 min. max. observation
Reason for termination	self-extinguished	

A smaller scale flammability evaluation for the flame barrier foam sheets was made using a simplified test set up. Referring to FIG. 4, the test set up **40** requires that the flame barrier foam sheet **24** be placed over a non-treated slab of polyurethane foam **42**. Optionally, a thermocouple **44** is installed between the flame barrier foam sheet **24** and the slab **42**. A fuel source **46** is placed over the flame barrier foam sheet **24**, such that the fuel source **46** is separated

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from the slab **42** by the flame barrier foam sheet **24**. The preferred fuel source was a scrap of carpet cushion foam of constant density that had been soaked in isopropyl alcohol to a constant liquid pick up. The fuel source **46** was ignited and allowed to burn until extinguished. The flame spread behavior and char formation were observed.

In the case of Examples A to F above, the fuel source **46** self extinguished before the underlying flame barrier foam sheet **24** or foam slab **42** ignited. This qualitative test thus establishes that the flame barrier foam sheets **24** prevented ignition or combustion of the underlying more combustible foam slab **42**. The flame barrier foam sheets **24** thus had good flame retardant properties, and all of the other Examples A, B and D to F similarly would be expected to be useful in helping to pass the California TB603 flammability test.

While Examples A to F are all considered within the scope of the invention, Examples D, E and F are particularly preferred. The RHOPLEX FR-1 binder has a glass transition temperature (Tg) of -17°C and a chlorine content of approx. 36% on a dry weight basis. The combination of low glass transition temperature and high chlorine content in the binder of the coating liquid yielded flame barrier foam sheets with better flammability performance and better cushioning performance than the flame barrier foam sheets of Examples A, B and C.

The invention has been illustrated by detailed description and examples of the preferred embodiments. Various changes in form and detail will be within the skill of persons skilled in the art. Therefore, the invention must be measured by the claims and not by the description of the examples or the preferred embodiments.

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